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Review of the distribution and new occurrences of *Lacunicambarus thomai* (Jezerinac, 1993) (Decapoda, Cambaridae) in Pennsylvania and its possible introduction outside of its native range

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Abstract

Recent investigations into the distributions of western Pennsylvania, USA, crayfishes have yielded 30 new occurrences of *Lacunicambarus thomai* (Jezerinac, 1993). The discovery of a population of *L. thomai* in Crawford County is the furthest north population in the state. Two populations of *L. thomai* were discovered outside of its historic range in Fayette and Somerset counties in southwestern Pennsylvania. These populations are in recreational fishing destinations and may have been introduced by bait bucket or construction fill. Additional surveys for Pennsylvania *L. thomai* should occur in areas lacking recent, thorough searches.

Keywords

Distribution, burrowing crayfish, introduced species

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Introduction

Lacunicambarus thomai (Jezerinac, 1993) (Little Brown Mudbug) is a primary burrowing crayfish found in the USA in central and eastern Ohio, western Pennsylvania, central and western West Virginia, eastern Kentucky, and a small part of Tennessee west of the Smoky Mountains (Jezerinac 1993; Jezerinac et al. 1995; Thoma and Jezerinac 2000; Taylor and Schuster 2004; Loughman and Simon 2011). Bottomland habitats including marshes, wetlands, and large river floodplains are preferred *L. thomai* habitats. Within its Appalachian distribution, *L. thomai* is replaced by members of the *Cambarus dubius* Faxon, 1884 complex, as well as *Cambarus monongalensis* Ortmann, 1905 along ridge top and hillside habitats conducive for primary burrowing crayfish species (Loughman and Simon 2011).

In Pennsylvania, *L. thomai* has been collected in Allegheny, Armstrong, Beaver, Butler, Fayette, Greene, Indiana, Jefferson, Lawrence, Mercer, Washington, and Westmoreland counties (Ortmann 1905, 1906; Loughman et al. 2017). While Ortmann (1905, 1906) did

search for northern populations near localities such as Pymatuning Swamp in Crawford County and Oil City in Venango County, he did not find *L. thomai* in these areas. Historically, *L. thomai* was collected in Jefferson County (Ortmann 1905, 1906) but was not found in this county in recent surveys (Loughman et al. 2017). Ortmann (1905, 1906) described *L. thomai* as being absent to the east of Pennsylvania's Chestnut Ridge (Fig. 1). However, Ortmann (1905) found *L. thomai* in association with *C. dubius* in at least one site at the base of the Chestnut Ridge (elevation = 326 m) near Dunbar, Fayette County. However, no other locality information was provided, specimens could not be located, and it is unknown which side of the Chestnut Ridge this locality falls on (Fig. 1). Ortmann's Dunbar record contradicts his own claims, as well as results from recent investigations because Ortmann (1905, 1906) claimed the distributions of *C. dubius* and *L. thomai* were allopatric, with *C. dubius* present on the eastern slope of the Chestnut Ridge and *L. thomai* present on the western slope. Both Loughman et al. (2017) and Allison (2020) also found *C. dubius* to be present on the eastern slope of the Chestnut Ridge, but not on the western slope. However, recent investigations into the distribution and ecology of other burrowing crayfishes (Allison 2020; Khan 2021; D. Davis unpublished data) have also yielded new populations of *L. thomai* in Pennsylvania, providing additional insight on the distribution of *L. thomai* in the state.

Methods

Burrowing crayfish surveys were conducted in Armstrong, Beaver, Butler, Crawford, Fayette, Greene, Somerset, Washington, and Westmoreland counties, Pennsylvania, USA from June 2017 to September 2020 (Figs. 2, 3). A total of 1,363 sites were visited, with most populations identified through searches in marshes, seeps, anthropogenic wetlands, and roadside ditches. Burrows with evidence of recent activity (mud pellets at burrow portals) were given sampling priority over burrows with no evidence of recent activity. Excavation was the primary means of collection and completed either by hand or with use of spades or picks. Most excavation was completed until resting chambers were breached, which were subsequently filled with water, and aggressively plunged by collectors. *Lacunicambarus thomai* normally would respond to these activities by rising to the air/water interface, where investigators captured them. Crayfish were collected under Type 1: Non-Profit Research and Education scientific collecting permits provided by the Pennsylvania Fish and Boast Commission, Pennsylvania, USA. Specimens were euthanized on site in 80% ethanol, and location and ecological data recorded. All voucher specimens were transferred to 70% ethanol in the laboratory and are housed in the West Liberty University (WLU) Astacology collection.

Results

***Lacunicambarus thomai* (Jezerinac, 1993)**
Figures 4A, E, 6A

Thirty new records of *L. thomai* were found in Armstrong, Beaver, Butler, Crawford, Fayette, Greene, Somerset, Washington, and Westmoreland counties. Of these, 27 records were collected within the known distribution of *L. thomai*. The majority of these records came from the Pennsylvania–West Virginia border in Beaver, Washington, and Greene counties (D. Davis unpublished data). Two populations of *L. thomai* were found between Pennsylvania's Chestnut Ridge and the Allegheny Mountains, outside of the known range of *L. thomai* (Fig. 3; Allison 2020). One of these populations (Fig. 4A) was discovered adjacent to Deer Lake, Wharton Township, Fayette County in the banks of the impoundment (39.8523, −079.5952; Fig. 4B), though the majority of burrows (Fig. 4C) and specimens were found in an adjacent roadside ditch system (39.8538, −079.5953: Fig. 4D). The population in the roadside ditch system appeared to be well established, as two ovigerous females were found in this area on 27 May 2019 (Fig. 4E). The other population was found in a roadside ditch (Fig. 5A) and adjacent floodplain of Cranberry Glade Lake (Fig. 5B–D) in State Game Lands 111, Lower Turkey Township, Somerset County (39.9045, −079.36914). Much like in Deer Lake, the Cranberry Glade Lake *L. thomai* population appeared to be established, with a female bearing live young collected on 28 May 2019. This latter population is the first known occurrence for *L. thomai* in Somerset County. A population of *L. thomai* (Fig. 6A) was also discovered in the extreme southern tip of Pymatuning State Park, where it was present in a large skunk cabbage wetland complex (Fig. 6B) with abundant clay substrate (Fig. 6C, D; Khan 2021). This locality (41.5060, −080.4733) is the first known occurrence of *L. thomai* in Crawford County, and is the furthest north population of this species in Pennsylvania. The following is a complete list of the new records of *L. thomai* in Pennsylvania from our surveys.

New Records. USA – **Pennsylvania** • Armstrong County, Lenape Heights, Crooked Creek Lake Wetland adjacent to Crooked Creek Lake, 6.72 miles (10.81 km) SW of Whitesburg; 40.7037, −079.5146; 4.VII.2020; Patrick Allison Jr. leg.; burrow excavation; 1 II♂, 1 ♀, 4 J, WLU 200704-02 • Beaver County, Clinton, Mineral Springs Loop Seep adjacent to PA-18, 2.89 miles (4.65 km) S of Harshaville; 40.5022, −080.4245; 27.V.2020; Destinee Davis, Taylor Whitson, Caitlin de Vries leg.; burrow excavation; 3 II♂, 2 ♀, WLU 200527-03a; 1 O♀, 72 J WLU 200527-03b • Beaver County, Frankfort, Traverse Creek Swamp #1, adjacent to Cabin Road, 2.72 miles (4.38 km) SW of Harshaville; 40.5081, −080.4358; 16.VI.2020; Destinee Davis, Taylor Whitson, Kaine Diehl leg.; burrow excavation; 1 II♂, WLU 200616-01 • same locality; 18.VI.2020; Destinee Davis, Taylor Whitson,

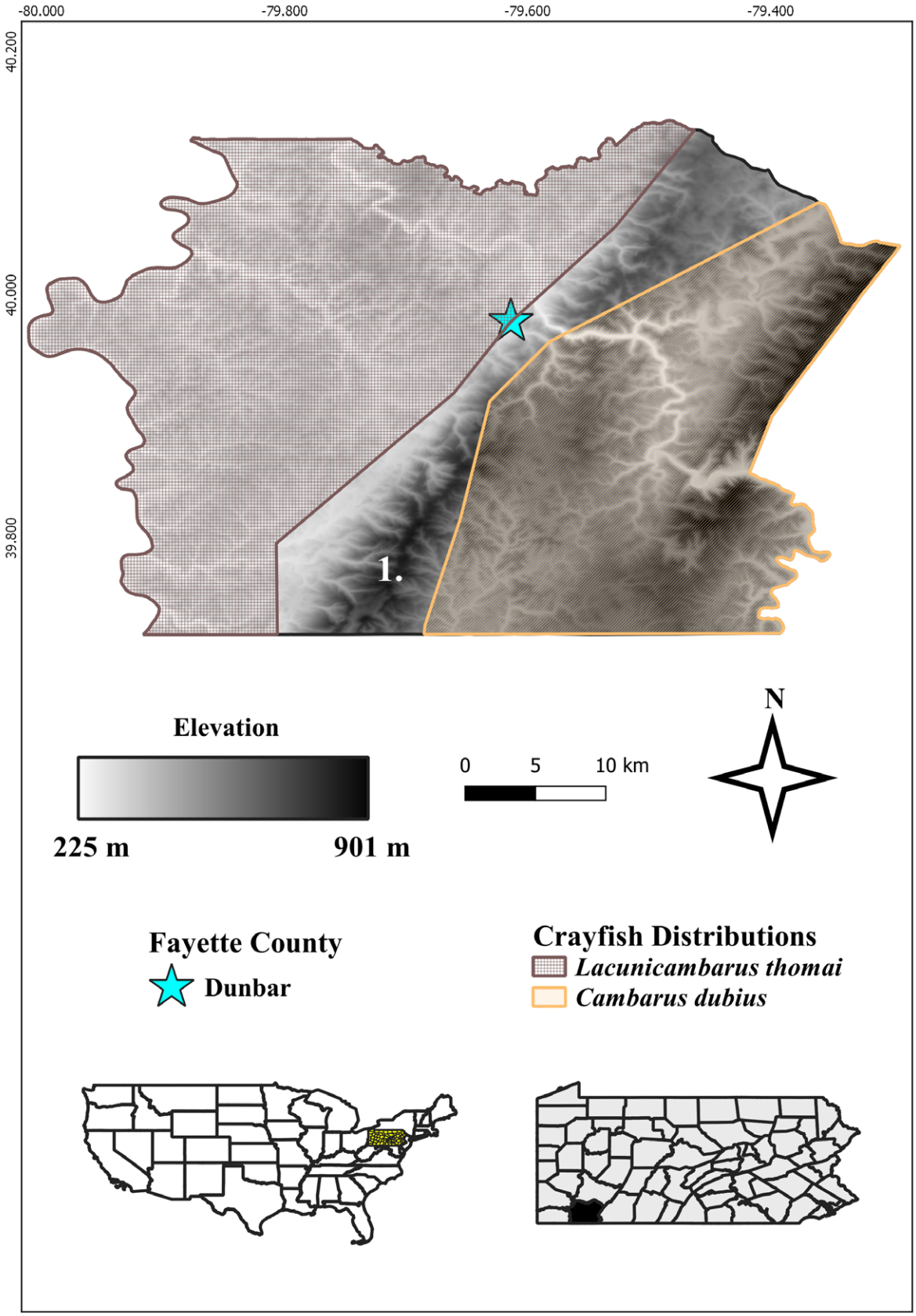

Figure 1. Distributions of *Cambarus dubius* and *Lacunicambarus thomai* in Fayette County in southwestern Pennsylvania (Ortmann 1905, 1906; Loughman et al. 2017; Allison 2020). The Chestnut Ridge (1) appears to act as a geographical boundary between the species. Ortmann (1905, 1906) described sympatric populations of *Cambarus dubius* and *Lacunicambarus thomai* at Dunbar, but specimen records are unavailable, and the precise collection location is unknown.

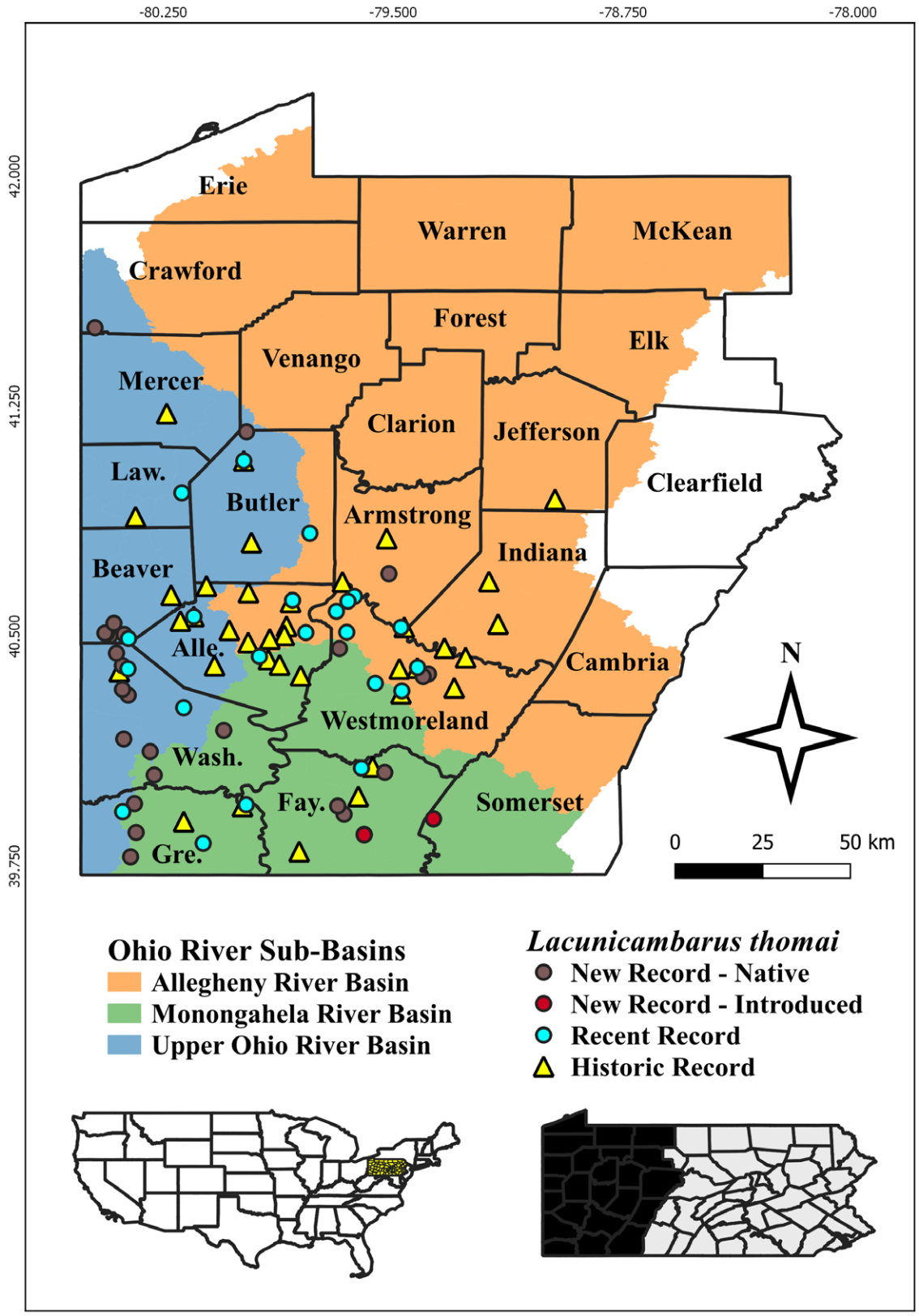

Figure 2. Collection sites of *Lacunicambarus thomai* in western Pennsylvania with listed counties and basins. Brown circles indicate new records in assumed native range and red circles indicate new records that may be potential introductions. Cyan circles indicate recent records from Loughman et al. (2017). Yellow triangles indicate historic records from Ortmann (1905, 1906) and the Smithsonian National Museum of Natural History (NMNH). Alle. = Allegheny, Fay. = Fayette, Gre. = Greene, Law. = Lawrence, Wash. = Washington.

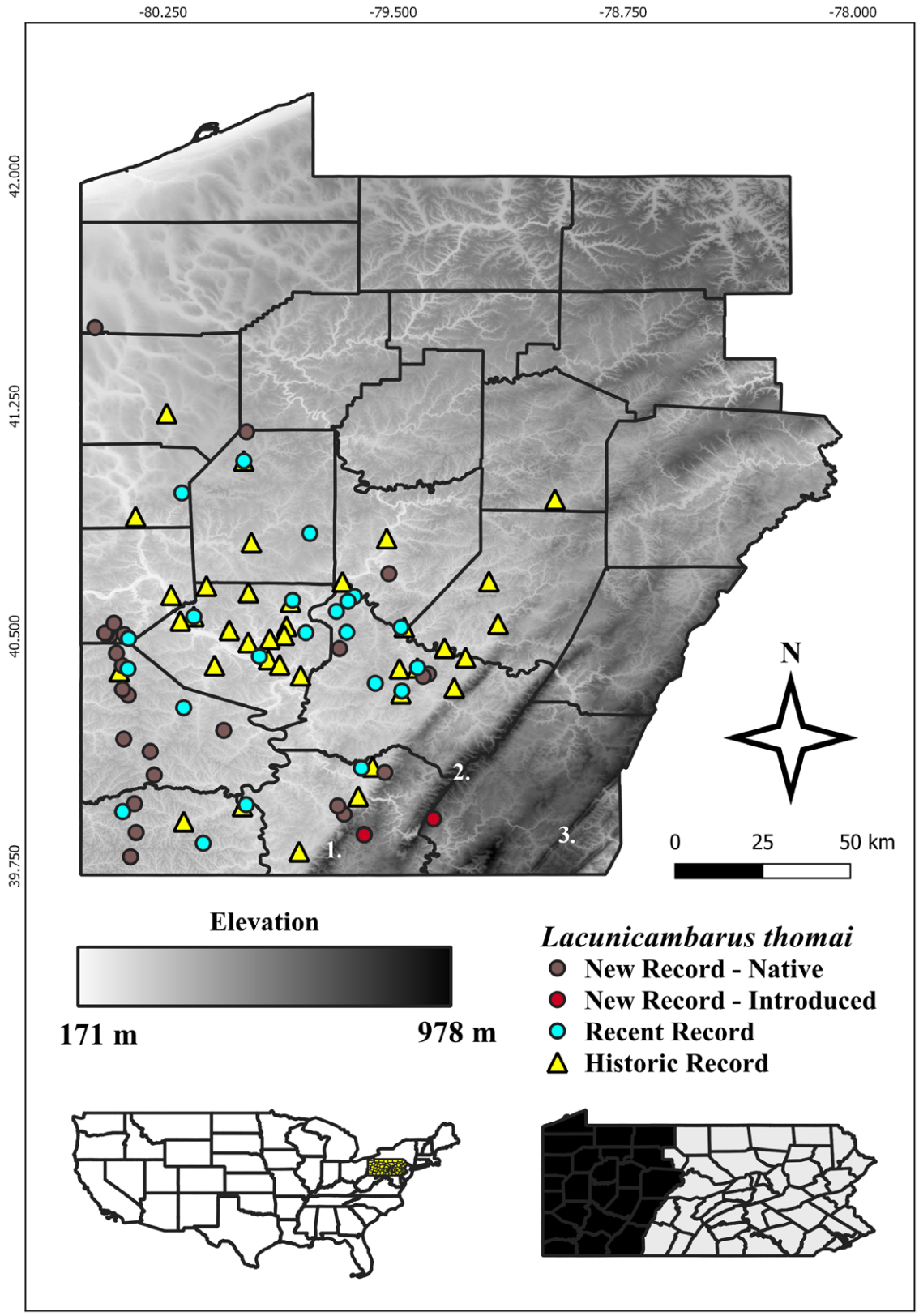

Figure 3. Collection sites of *Lacunicambarus thomai* in western Pennsylvania with elevation displayed. Brown circles indicate new records in assumed native range and red circles indicate new records that may be potential introductions. Cyan circles indicate recent records from Loughman et al. (2017). Yellow triangles indicate historic records from Ortmann (1905, 1906) and the Smithsonian National Museum of Natural History (NMNH). The historic range of *L. thomai* falls to the west of the Chestnut Ridge (1), Laurel Ridge (2), and Allegheny Mountains (3).

Table 1. *Lacunicambarus thomai* records in Pennsylvania, USA. Records are distinguished as historic (≥50 years old), recent (<50 years old, but not from this study), new (this study only), and introduced (records between the Chestnut Ridge and Allegheny Mountains). Sites marked as historic and recent are historic sites that were revisited. Sources for these data include this study (indicated by —), Ortmann (1905, 1906), and Loughman et al. (2017). Smithsonian NMNH = Smithsonian National Museum of Natural History.

Country	State	County	City	Latitude	Longitude	Source	Year	Historic	Recent	New	Introduced
USA	Pennsylvania	Allegheny	Carnegie	40.4044	−080.0833	Ortmann (1905, 1906)	1898	X			
USA	Pennsylvania	Allegheny	Harmar	40.5328	−079.8486	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Allegheny	Sewickly Heights	40.5642	−080.1508	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Allegheny	Pittsburgh	40.4797	−079.9736	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Allegheny	North Versailles	40.3714	−079.8025	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Allegheny	Russelton	40.6111	−079.8356	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Allegheny	Pittsburgh	40.4240	−079.9076	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Allegheny	Pittsburgh	40.5033	−079.8558	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Allegheny	Aspinwall	40.4911	−079.9031	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Allegheny	Warrendale	40.6639	−080.1097	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Allegheny	Gibsonia	40.6425	−079.9728	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Allegheny	Sewickly	40.5497	−080.1947	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Allegheny	Braddock	40.4067	−079.8711	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Allegheny	Pittsburgh	40.5197	−080.0353	Smithsonian NMNH	1906	X			
USA	Pennsylvania	Allegheny	Russellton	40.6172	−079.8290	Loughman et al. (2017)	2014	X	X		
USA	Pennsylvania	Allegheny	Leechburg	40.6299	−079.6273	Loughman et al. (2017)	2014	X	X		
USA	Pennsylvania	Allegheny	Plum	40.5119	−079.7856	Loughman et al. (2017)	2014		X		
USA	Pennsylvania	Allegheny	Lower Burrell	40.6141	−079.6481	Loughman et al. (2017)	2014		X		
USA	Pennsylvania	Allegheny	Sewickly Heights	40.5642	−080.1508	Loughman et al. (2017)	2014	X	X		
USA	Pennsylvania	Allegheny	Pittsburgh	40.4342	−079.9370	Loughman et al. (2017)	2014		X		
USA	Pennsylvania	Armstrong	Lenape Heights	40.7037	−079.5147	—	2020			X	
USA	Pennsylvania	Armstrong	Kittanning	40.8189	−079.5219	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Armstrong	Saltsburg	40.5294	−079.4644	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Beaver	Clinton	40.5022	−080.4245	—	2020			X	
USA	Pennsylvania	Beaver	Frankfort	40.5081	−080.4358	—	2020			X	
USA	Pennsylvania	Beaver	Georgetown	40.5095	−080.4406	—	2020			X	
USA	Pennsylvania	Beaver	Georgetown	40.5105	−080.4406	—	2020			X	
USA	Pennsylvania	Beaver	Clinton	40.5060	−080.3780	—	2020			X	
USA	Pennsylvania	Beaver	Harshaville	40.5421	−080.4116	—	2020			X	
USA	Pennsylvania	Beaver	Baden	40.6339	−080.2250	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Beaver	Township of Hanover	40.4926	−080.3639	Loughman et al. (2017)	2015		X		
USA	Pennsylvania	Butler	Harrisville	41.1665	−079.9790	—	2017			X	
USA	Pennsylvania	Butler	Slippery Rock	41.0719	−079.9881	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Butler	Renfrew	40.8056	−079.9631	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Butler	Slippery Rock	41.0718	−079.9878	Loughman et al. (2017)	2015	X	X		
USA	Pennsylvania	Butler	Herman	40.8357	−079.7725	Loughman et al. (2017)	2015		X		
USA	Pennsylvania	Butler	Portersville	40.9674	−080.1900	Loughman et al. (2017)	2015		X		

Country	State	County	City	Latitude	Longitude	Source	Year	Historic	Recent	New	Introduced
USA	Pennsylvania	Crawford	Pymatuning South	41.5060	−080.4733	—	2019			X	
USA	Pennsylvania	Fayette	Connellsville	40.0558	−079.5281	—	2019			X	
USA	Pennsylvania	Fayette	Lemont Furnace	39.9193	−079.6608	—	2019			X	
USA	Pennsylvania	Fayette	Uniontown	39.9464	−079.6814	—	2019			X	
USA	Pennsylvania	Fayette	Ohiopyle	39.8539	−079.5954	—	2019			X	X
USA	Pennsylvania	Fayette	Ohiopyle	39.8523	−079.5953	—	2019			X	X
USA	Pennsylvania	Fayette	Dunbar	39.9778	−079.6144	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Fayette	Connellsville	40.0742	−079.5678	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Fayette	Smithfield	39.7978	−079.8072	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Fayette	Owensdale	40.0700	−079.6041	Loughman et al. (2017)	2015		X		
USA	Pennsylvania	Greene	Graysville	39.9539	−080.3446	—	2020			X	
USA	Pennsylvania	Greene	Graysville	39.9281	−080.3823	—	2020			X	
USA	Pennsylvania	Greene	Freeport	39.7806	−080.3573	—	2020			X	
USA	Pennsylvania	Greene	Holbrook	39.8600	−080.3391	—	2020			X	
USA	Pennsylvania	Greene	Rices Landing	39.9453	−079.9922	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Greene	Waynesburg	39.8956	−080.1839	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Greene	Graysville	39.9278	−080.3830	Loughman et al. (2017)	2015		X		
USA	Pennsylvania	Greene	Morrisville	39.8248	−080.1203	Loughman et al. (2017)	2015		X		
USA	Pennsylvania	Greene	Rices Landing	39.9505	−079.9802	Loughman et al. (2017)	2015	X	X		
USA	Pennsylvania	Indiana	Creekside	40.6783	−079.1883	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Indiana	Homer City	40.5397	−079.1586	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Jefferson	Punxsutawney	40.9464	−078.9728	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Lawrence	Wampum	40.8900	−080.3408	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Mercer	Mercer	41.2264	−080.2394	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Somerset	Confluence	39.9046	−079.3691	—	2019			X	X
USA	Pennsylvania	Washington	Claysville	40.1648	−080.3794	—	2020			X	
USA	Pennsylvania	Washington	Avella	40.3076	−080.3649	—	2020			X	
USA	Pennsylvania	Washington	Burgettstown	40.3265	−080.3837	—	2020			X	
USA	Pennsylvania	Washington	Burgettstown	40.4043	−080.3840	—	2020			X	
USA	Pennsylvania	Washington	Washington	40.1240	−080.2933	—	2020			X	
USA	Pennsylvania	Washington	Prosperity	40.0474	−080.2802	—	2020			X	
USA	Pennsylvania	Washington	Eighty Four	40.1930	−080.0533	—	2020			X	
USA	Pennsylvania	Washington	Burgettstown	40.4447	−080.4032	—	2020			X	
USA	Pennsylvania	Washington	Burgettstown	40.3850	−080.3942	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Washington	Joffre	40.3939	−080.3657	Loughman et al. (2017)	2015	X	X		
USA	Pennsylvania	Washington	Canonsburg	40.2669	−080.1839	Loughman et al. (2017)	2015		X		
USA	Pennsylvania	Westmoreland	Murrysville	40.4599	−079.6758	—	2020			X	
USA	Pennsylvania	Westmoreland	New Alexandria	40.3768	−079.3858	—	2020			X	
USA	Pennsylvania	Westmoreland	New Alexandria	40.3688	−079.4029	—	2020			X	
USA	Pennsylvania	Westmoreland	Blairsville	40.4306	−079.2644	Ortmann (1905, 1906)	1905	X			

Country	State	County	City	Latitude	Longitude	Source	Year	Historic	Recent	New	Introduced
USA	Pennsylvania	Westmoreland	Blairsville	40.4614	−079.3333	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Westmoreland	Derry	40.3317	−079.3017	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Westmoreland	New Alexandria	40.3967	−079.4219	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Westmoreland	Crabtree	40.3935	−079.4804	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Westmoreland	Greensburg	40.3131	−079.4753	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Westmoreland	Freeport	40.6772	−079.6661	Ortmann (1905, 1906)	1905	X			
USA	Pennsylvania	Westmoreland	Greensburg	40.3466	−079.5588	Loughman et al. (2017)	2015		X		
USA	Pennsylvania	Westmoreland	Lower Burrell	40.5810	−079.6859	Loughman et al. (2017)	2015		X		
USA	Pennsylvania	Westoreland	Avonmore	40.5288	−079.4751	Loughman et al. (2017)	2015	X	X		
USA	Pennsylvania	Westoreland	New Alexandria	40.3981	−079.4210	Loughman et al. (2017)	2015	X	X		
USA	Pennsylvania	Westoreland	Murrysville	40.5130	−079.6522	Loughman et al. (2017)	2015		X		
USA	Pennsylvania	Westoreland	Latrobe	40.3215	−079.4724	Loughman et al. (2017)	2015	X	X		

Kaine Diehl leg.; burrow excavation; 1 ♀, WLU 200618-01 • Beaver County, Georgetown, Roadside seep adjacent to Cabin Road, 2.77 miles (4.46 km) SW of Harshaville; 40.5094, −080.4405; 8.VII.2020; Destinee Davis, Taylor Whitson leg.; burrow excavation; 1 II♂, WLU 200708-01 • Beaver County, Georgetown, Upper Dam RCSP adjacent to Group Camping Area Lake, 2.71 miles (4.36 km) SW of Harshaville; 40.5105, −080.4406; 8.VII.2020; Destinee Davis, Taylor Whitson leg.; burrow excavation; 1 II♂, WLU 200708-02 • Beaver County, Clinton, Traverse Creek floodplain, adjacent to Heritage Trail Lot, 3.09 miles (4.97 km) SE of Harshaville; 40.5060, −080.3780; 7.VIII.2020; Destinee Davis, Taylor Whitson leg.; burrow excavation; 1 II♂, WLU 200807-01 • Beaver County, Harshaville, Little Traverse Creek at crossing of Lincoln Hwy (Hwy 30), 4.66 miles (7.50 km) NE of Frankfort Springs; 40.5421, −080.4115; 1.VI.2017; Tanya Khan, Sarah Harmon, Greg Myers, Riley Aulick leg.; burrow excavation; 1 O♀, 63J, WLU 170601-09 • Butler County, Harrisville, North Branch Slippery Rock Creek at crossing of White Oak Rd (T477), 1.77 miles (2.85 km) S of Barkeyville; 41.1665, −079.9789; 20.VII.2017; Tanya Khan, Zachary Loughman, Riley Aulick leg.; burrow excavation; 1 ♀, 1 J, WLU 170720-07 • Crawford County, Pymatuning South, Seep and UNT of Pymatuning Reservoir, 2.36 miles (3.80 km) NE of Jamestown; 41.5060, −080.4733; 18.VIII.2019; Tanya Khan, Patrick Allison Jr., Destinee Davis leg.; burrow excavation; 1 II♂, 2 ♀, WLU 190816-112 • Fayette County, Ohiopyle, Roadside ditch adjacent to Green Brier Rd, 1.6 miles (2.57 km) E of Chalk Hill; 39.8538, −079.5953; 27.V.2019; Patrick Allison Jr. leg.; burrow excavation; 2 I♂, 2 O♀, 1 ♀, 2 J, WLU CD-LT-190527-01 • Fayette County, Ohiopyle, Floodplain of Deer Lake on Chalk Hill-Ohiopyle Rd, 1.5 miles (2.41 km) E from Chalk Hill; 39.8523, −079.5952; 27.V.2019; Patrick Allison Jr. leg.; burrow excavation; 1 ♀, WLU CD-LT-190527-02 • Fayette County, Connellsville, Roadside ditch adjacent to Breakneck Rd, 2.47 miles (3.98 km) S of Wooddale; 40.0558, −079.5281; 30.VII.2019; Patrick Allison Jr. leg.; burrow excavation; 1 II♂, 1 J, WLU CD-LT-190730-01 • Fayette County, Lemont Furnace, Roadside ditch/wetland adjacent to Yauger Hollow Rd, 1.7 miles (2.74 km) SW of Mt. Braddock; 39.9192, −079.6607; 14.VIII.2019; Patrick Allison Jr. leg.; burrow excavation; 1 ♀, WLU CD-LT-190814-01 • Fayette County, Uniontown, Roadside ditch adjacent to Carr Rd, 1.9 miles (3.06 km) W of Mt. Braddock; 39.9463, −079.6813; 14.VIII.2019; Patrick Allison Jr. leg.; burrow excavation; 1 J, WLU CD-LT-190814-02 • Greene County, Graysville, Roadside ditch adjacent to Webster Rd, 2.02 miles (3.25 km) W of Nineveh; 39.9538, −080.3445; 29.V.2020; Destinee Davis, Patrick Allison Jr., Caitlin de Vries leg.; burrow excavation; 2 II♂, WLU 200529-01 • Greene County, Graysville, Roadside ditch adjacent to Hidden Valley Rd, 4.57 miles (7.35 km) SW of Nineveh; 39.9280, −080.3822; 23.VII.2020; Destinee Davis, Taylor Whitson leg.; burrow excavation; 1 II♂, WLU 200723-10 • Greene County, Freeport, Roadside

Figure 4. A. *Lacunicambarus thomai*. **B.** Active burrow at Deer Lake, Fayette County impoundment. **C.** Active burrow. **D.** Roadside ditch adjacent to Deer Lake where *L. thomai* occurs. **E.** Ovigerous specimen.

ditch adjacent to Blockhouse Rd, 0.6 miles (0.97 km) NE of Ashtree, 39.7806, −080.3573; 25.VII.2020; Patrick Allison Jr. leg.; burrow excavation; 1 ♀, WLU 200725-01 • Greene County, Holbrook, Roadside ditch adjacent to Hampton Rd, 1.56 miles (2.51 km) NW of Woodruff; 39.8599, −080.3391; 27.IX.2020; Destinee Davis leg.; burrow excavation; WLU 200927-02 • Somerset County, Confluence, Roadside ditch/floodplain adjacent to Cranberry Rd, in SGL-111 next to Cranberry Glade Lake, 3.6 miles (5.79 km) N of Draketown; 39.9045, −079.3691; 27.V.2019; Patrick Allison Jr., Destinee Davis, Emma McClelland leg.; burrow excavation; 1 O♀, 3 J, WLU CD-LT-190528-01 • Washington County, Claysville, Ditch at Taylorstown Ballfields off Buffalo Creek Rd, 7.07 miles (11.38 km) W of Washington; 40.1647, −080.3794; 4.VIII.2020; Destinee Davis, Taylor Whitson, Christian Beall leg.; burrow excavation; 1 II♂, WLU 200804-11 • Washington County, Avella, Forested Wetland upstream of Serenity Farm Rd crossing, 3.02 miles (4.86 km) W of Hickory; 40.3076, −080.3648; 16.V.2020; Destinee Davis leg.; burrow excavation; 1 O♀, 174 J, WLU 200516-01 • Washington County, Burgettstown, Skunk Cabbage Wetland adjacent to Atlasburg Road, 1.05 miles (1.69 km) S of Atlasburg; 40.3264, −080.3837; 21.V.2020; Destinee Davis leg.; burrow excavation; 1 I♂, WLU 200521-01 • Washington County, Burgettstown, Wetland adjacent to Bavington Rd, 4.04 miles (6.50 km) SW of Robinson; 40.4043, −080.3839; 22.VI.2020; Kaine Diehl, Addie Shanor leg.; burrow excavation; 1 ♀, WLU 200622-12 • Washington County, Washington,

Figure 5. A. Roadside ditch adjacent to Cranberry Glade Lake in State Game Lands 111, Somerset County where *Lacunicambarus thomai* occurs. **B.** Small tributary flowing from Cranberry Glade Lake with its nearby floodplain. **C.** Floodplain of Cranberry Glade Lake and nearby tributary where *L. thomai* occurs. **D.** Burrows present in the adjacent floodplain.

Floodplain of UNT into Chartiers Creek, 0.79 miles (1.27 km) NE of Green Hill; 40.1239, −080.2932; 22.VI.2020; Destinee Davis, Taylor Whitson leg.; burrow excavation; 1 II♂, WLU 200622-21 • Washington County, Prosperity, Roadside seep adjacent to Bell's Lake Road, 4.02 miles (6.47 km) W of Amity; 40.0474, −080.2801; 22.VI.2020; Destinee Davis, Taylor Whitson leg.; burrow excavation; 1 ♀, WLU 200622-22 • Washington County, Eighty Four, Ephemeral pool adjacent to Mingo Creek Road, 3.77 miles (6.07 km) S of Venetia; 40.1929, −080.0532; 23.VI.2020; Kaine Diehl, Addie Shanor leg.; burrow excavation; 1 II♂, 1 ♀, WLU 200623-11 • Washington County, Burgettstown, Roadside ditch adjacent to T446, 3.52 miles (5.66 km) E of Robinson; 40.4446, −080.4031; 24.IX.2020; James Krochmal leg.; burrow excavation; 1 ♀, WLU 200924-03 • Westmoreland County, Murrysville, UNT of Haymakers Run/Lou Remaley Complex Run, 3.42 miles (5.50 km) SW of Wiester; 40.4598, −079.6757; 11.VII.2020; Patrick Allison Jr. leg.; burrow excavation; 1 II♂, 1 J, WLU 200711-01 • Westmoreland County, New Alexandria, UNT of Keystone Lake, 4.08 miles (6.57 km) NW of New Derry; 40.3768, −079.3858; 11.VII.2020; Patrick Allison Jr. leg.; burrow excavation; 1 II♂, WLU 200711-02 • Westmoreland County, New Alexandria, Roadside ditch adjacent to Slag Road, 4.73 miles (7.61 km) NW of New Derry; 40.3688, −079.4029; 11.VII.2020; Patrick Allison Jr. leg.; burrow excavation; 1 ♀, 1 J, WLU 200711-03.

Identification. We identified *L. thomai* by its dark brown coloration, obliterated areola, suborbital angle, and large, heavy chelae with numerous rows of tubercles on the palm and lacking setae at the base of its fixed finger. This differs from the primary burrowing crayfish that is dominant in Pennsylvania's Allegheny Mountain province, *Cambarus dubius*, which has a bright orange to dark red coloration and lacks an obliterated areola. The primary burrowing crayfish *Creaserinus fodiens* (Cottle, 1863) lacks a suborbital angle and has setae at the base of its fixed finger, as well as a well-defined dactyl notch with an enlarged tubercle anterior to the notch. *Cambarus carinirostris* Hay, 1914, a secondary burrowing crayfish, lacks an obliterated areola and has a single row of adpressed tubercles on the palm of the chelae.

Discussion

The updated county localities where *Lacunicambarus thomai* occurs are the following: Allegheny, Armstrong, Beaver, Butler, Crawford, Fayette, Greene, Indiana, Jefferson, Lawrence, Mercer, Somerset, Washington, and

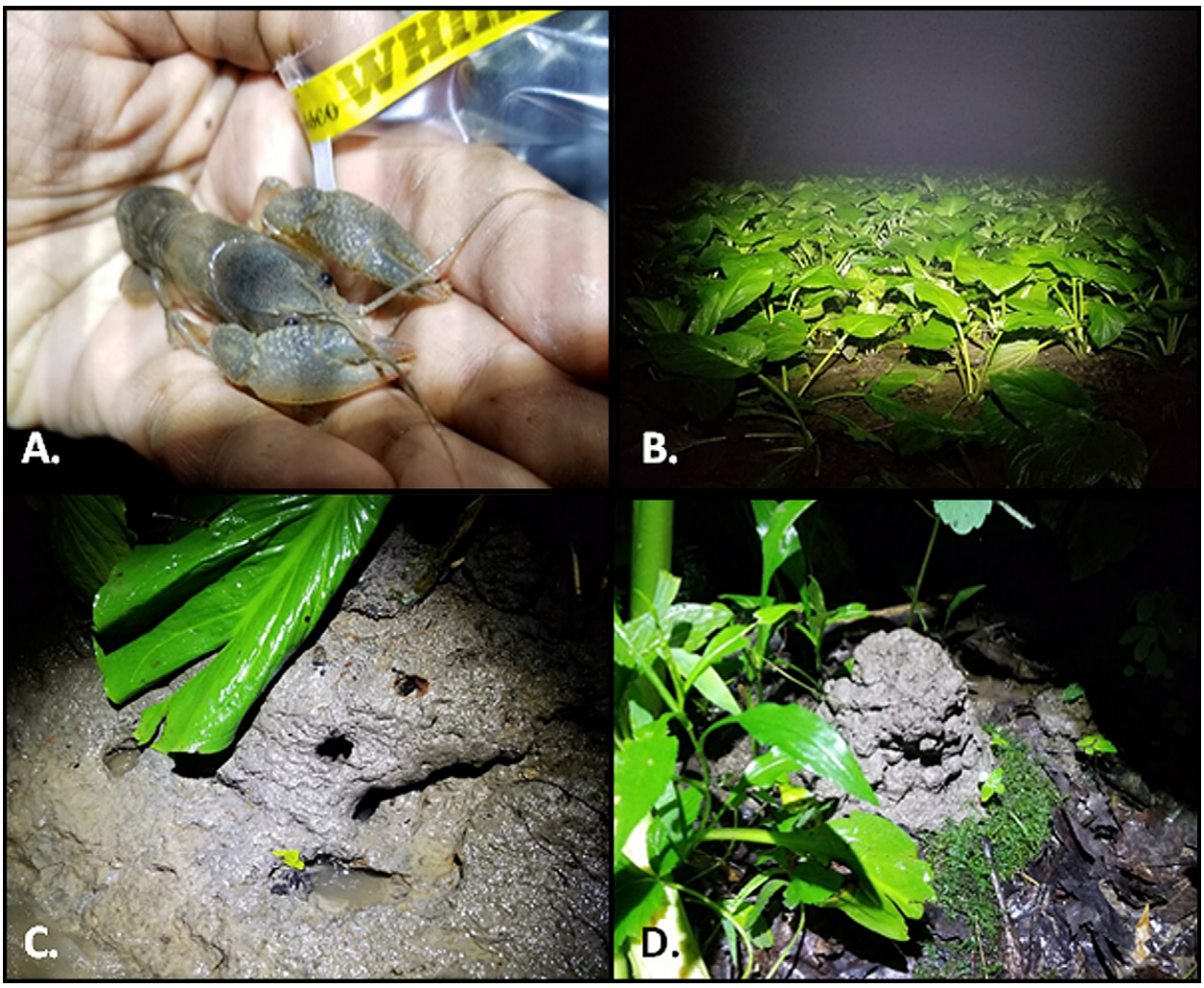

Figure 6. A. Freshly molted *Lacunicambarus thomai*. **B.** Skunk cabbage wetland complex in Pymatuning State Park, Crawford County where *L. thomai* occurs. **C.** Burrows present in clay substrate of wetland. **D.** Crayfish chimney present in wetland.

Westmoreland counties (Ortmann 1905, 1906; Loughman et al. 2017; this study). *Lacunicambarus thomai* occupies a large portion of the Ohio River basin in western Pennsylvania. It is found throughout the majority of the Upper Ohio River basin, but appears to be absent in the northern parts of the Allegheny River basin. Historically, this species was found as far west as Punxsutawney in Jefferson County (Ortmann 1905, 1906), but recent surveys (Allison 2020; Khan 2021; D. Davis unpublished data) have not included this part of the state. The population of *L. thomai* at the southern end of Pymatuning State Park, Crawford County, is the furthest north population known in Pennsylvania. While being near a large reservoir may suggest a potential introduction, we believe the population is native because it was found in a skunk cabbage wetland in a relatively undisturbed area about 36.7 km northwest of its historic range in the northern Upper Ohio River basin in Mercer County (Ortmann 1905, 1906). In addition, *L. thomai* was recently found as far north as Portersville, Lawrence County and Slippery Rock, Butler County (Loughman et al. 2017). Extensive roadside surveys for *C. fodiens* resulted in the discovery of this population; however, no *L. thomai* populations were found elsewhere in Pymatuning State Park, nor in Pennsylvania's Lake Erie basin (Khan 2021). A new population of *L. thomai* was found in the Upper Ohio River basin <0.8 km south of Venango County in the headwaters of North Branch Slippery Rock Creek, Harrisville, Butler County. A small part of the Upper Ohio River basin extends into Venango County, and additional populations may be further upstream near Barkeyville, Venango County in North Branch Slippery Rock Creek or East Branch Wolf Creek. *Lacunicambarus thomai* may also be in roadside ditches or other suitable habitat near these streams.

In the Monongahela River basin, the discovery of *L. thomai* populations in the Allegheny Mountain Province is particularly intriguing, as these records are outside the known distribution of *L. thomai* in Pennsylvania. Prior to Allison (2020), the most recent survey for burrowing crayfishes in western Pennsylvania (Loughman et al. 2017) did not discover *L. thomai* east of the Chestnut Ridge. As previously stated, Ortmann (1905, 1906) defined the southeastern extent of *L. thomai* being the Chestnut Ridge (Figs. 1, 3), but described a population of *L. thomai* occurring sympatrically with *C. dubius* at

lower elevations along the Chestnut Ridge. Ortmann (1905, 1906) described *C. dubius* as being limited to southwestern Pennsylvania between the Chestnut Ridge and Allegheny Mountain front. Both Loughman et al. (2017) and Allison (2020) agreed with this distribution; furthermore, Allison (2020) found populations of *C. dubius* and *L. thomai* on directly opposite slopes of the Chestnut Ridge (*C. dubius* on the eastern slope and *L. thomai* on the western slope; Fig. 1). While *L. thomai* was reported to have entered the Allegheny Mountain Province in West Virginia, this has only occurred in the extreme southwestern edge of the physiographic province; it is replaced by *C. dubius* in all other areas of this province (Jezerinac et al. 1995). This would indicate that a natural barrier exists between the two species (the Chestnut Ridge; Fig. 1), and perhaps Ortmann was in error when describing the sympatric occurrence of *L. thomai* and *C. dubius* near Dunbar, Fayette County (Fig. 1; no specimen records from Ortmann's collections represent a population of *C. dubius* near Dunbar). Both populations of *L. thomai* found east of the Chestnut Ridge were found associated with man-made impoundments (Deer Lake and Cranberry Glade Lake). Burrows were excavated in the areas surrounding these sites and no additional populations of *L. thomai* were found; instead, *C. dubius* was present. It is possible that *L. thomai* may still be present at other localities in between the Chestnut Ridge and Allegheny Mountains; however, no additional populations were discovered during surveys for *C. dubius* (Allison 2020).

With the Chestnut Ridge acting as a seemingly natural barrier between *L. thomai* and *C. dubius*, these isolated occurrences of *L. thomai* in association with man-made impoundments may be resultant of an introduction. *Lacunicambarus thomai* has been reported as introduced in western Maryland, where it was found in the northern reaches of Deep Creek Lake, an area with heavy anthropogenic use (Loughman 2010). An exuvia of *Procambarus acutus* (Girard 1852), an introduced species in southwestern Pennsylvania, was found adjacent to the *L. thomai* colony in the floodplain of Cranberry Glade Lake. With one exotic crayfish introduction occurring in this locality, it is plausible that *L. thomai* may have been a bait bucket introduction to this area. While primary burrowing crayfish spend the majority of their lives within the complex burrows they construct, some species can be found in open waters seasonally (Hobbs 1942, 1981; Loughman and Simon 2011). *Lacunicambarus thomai* can be found in open water during early spring (Jezerinac et al. 1995; Loughman and Simon 2011) and late winter (Loughman and Simon 2011), making it possible for this species to be collected as bait, though during limited times of the year. Another introduction method that has been suggested for burrowing crayfishes is through the transportation of construction fill, with a population of *Cambarus loughmani* Foltz et al., 2018 at Chief Logan State Park, West Virginia, potentially introduced by this method (Foltz et al. 2018). This may explain why these particular *L. thomai* populations are present along roadways; if introduced through this method, they may have migrated over land to nearby impoundments.

Interactions between *L. thomai* and *C. dubius* populations have not been well-studied. In West Virginia, *L. thomai* and *C. dubius* were reported to co-occur with each other (Jezerinac et al. 1995), but it was not specified if these were true *C. dubius* or another member of the *C. dubius* complex. *Lacunicambarus thomai* has been found in association with another burrowing crayfish, *C. fodiens* in West Virginia (Jezerinac et al. 1995). These studies suggest that *L. thomai* and *C. dubius* may be able to co-exist in Pennsylvania. While it is plausible that *L. thomai* was introduced in these areas, there are over 100 localities between the Chestnut Ridge and Allegheny Mountains with crayfish burrows that have not been excavated and the species creating the burrows is unknown (Allison 2020). It is recommended that these localities be investigated further to better understand not only the distribution of *L. thomai* in the Allegheny Mountain province, but also the overall abundance of *C. dubius* in the area. Private citizens that live in the vicinity of suspected *L. thomai* introduction sites should be interviewed to determine how long *L. thomai* has occurred in the area and if construction fill has been deposited in the vicinity of the introduction sites. The challenge to this approach is that private citizens are not likely to be able to distinguish *L. thomai* from *C. carinirostris*, a native crayfish that also constructs burrows and occurs throughout western Pennsylvania. Furthermore, a thorough investigation of the distribution of *L. thomai* in western Pennsylvania is needed, as was done for *C. dubius* by Allison (2020). These surveys should focus on areas without recent thorough surveys such as Armstrong, Jefferson, Lawrence, Mercer, and Venango counties.

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Authors' Contributions

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tion: PFA, TNK, DAD. Methodology: ZJL, PFA. Project administration: ZJL, DAL. Resources: ZJL. Supervision: ZJL, DAL. Writing – original draft: PFA, ZJL. Writing – review and editing: PFA, DAL.

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